

The Effect of a Rigid Connection between the Slab and the Coupled Beam on the Seismic Performance of the Coupling Wall System

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Abstract: The evolution of the construction building is one of the urgent matters in the current era, especially for high and medium-rise buildings. The widely used frame shear wall system has the main sign for the resistance of the lateral load (seismic and wind loads), so adding the coupled shear wall system to the construction building can give sufficient lateral stability, which can be achieved by increasing stiffness, strength, and ductility of the system. However, much research had been studied the coupling beams in the shear wall system theoretically and experimental; the effectiveness of the slab performance on the system has a short thesis executed experimental with limiting factors. In other words, only a few studies have shown the effects of slabs on the behavior of the coupled beam, and these studies did not mention the representation of the model. This study aims to investigate the effect of the rigidity connection between the slab and coupled beam and to create a finite element model in 3D to get a full understanding of the behavior of the system with different cases and hence to get recommendations for constructing stability system, the interaction between the slab elements and the shear wall system can effect on the behavior of the building. Deformation, shear, and moment in the coupled beam consider as the main measurements of structure response; the measured responses with different models of building 4, 8, 12 stories have been investigated in 3D models to obtain the behavior of the interaction of the slab with the coupled wall system. Two cases have been created; one is made without slab between coupled beam, and the other with existence the slab. The results prove that the rigidity between the coupled beam and the slab diaphragm is more effective for stability versus the seismic load. It shows the response reduction in the coupled beam and hence the overall response of the structure modeling, which can be returned to the effects of interaction rigidity between elements of the coupled beam and slab.

Keywords: finite elements, coupling beam, diaphragm.

板與連梁剛性連接對連牆系統抗震性能的影響

摘要：建築建築的演進是當今時代亟待解決的問題之一，尤其是對中高層建築而言。廣泛使用的框架剪力牆系統的主要標誌是抗側向荷載（地震和風荷載），因此在建築建築中加入耦合剪力牆系統可以提供足夠的橫向穩定性，這可以通過增加剛度來實現，系統的強度和延展性。然而，對剪力牆體系中連梁的理論和試驗研究較多；板性能對系統的有效性有一個簡短的論文，在限制因素的情況下進行了實驗。換句話說，只有少數研究表明了對耦合梁行為的影響，而這些研究沒有提到模型的表示。本研究旨在研究板與連梁之間剛度連接的影響，並在3D中創建有限元模型，以全面了解系統在不同情況下的行為，從而為構建穩定系統提供建議，板構件和剪力牆系統之間的相互作用會影響建築物的性能。耦合梁中的變形、剪切和彎矩被認為是結構響應的主要測量；在3D模型中研究了4、8、12層不同模型的測量響應，以獲得板與耦合牆系統相互作用的行為。已創建兩個案例；一種是連梁間無板，另一種是有板。結果證明，耦合梁和平板隔板之間的剛度對穩定性比地震載荷更有效。它顯示了耦合梁中的響應減少，從而顯示了結構建模的整體響應，這可以返回到耦合梁和板的元素之間

的相互作用剛度的影響。

关键词：有限元、連梁、隔板。

1. Introduction

With the current era, the rapid growth in the construction high and medium-rise building had happened, so there is an orientation to enforce the resistance of lateral load by increasing capacity demand versus the seismic demand, coupled shear wall system is one of the systems which can play an important role for achieving the stability of the construction under seismic and wind loads, it frequently preferred in the building due to the seismic resistance mechanism, it contains the coupling beam and shear wall, however this system has the link between coupling beam and the shear wall which can contribute in increasing the energy dissipation, so the importance of diligently using the coupling wall system as a structural mechanism is the main factor for resistance the seismic and wind load, they comprise two or more individual wall connected to each other by coupling beam over the height of the building, in most cases, the connection links can start from the first level, and the resistance of the overturning moment can be sorted by two mechanisms, first is the moment resistance by the walls and the other by the axial force induced in the coupling beam.

Accordingly, the coupling beams have significantly reduced the overturning moment produced from the lateral loading. Moreover, the slab thickness effects and its rigidity on the coupling wall system have not been fully investigated until now. Few researchers studied only the response with limited parameters and without determining the overall behavior of the building. Therefore, research has been conducted to study rigidity effects between the slab and coupled beam. Overall, the outcomes confirm the significant effects of the rigidity connection on the seismic demands that necessitate taking into consideration from the initiating planning phase of building to reduce the vulnerability and increase the structural safety.

This study aims to investigate the effectiveness of the slab in the response of coupling shear wall system, which has been studied for different models 4, 8, 12 stories. Also, study the overall response of the construction building due to the seismic load, represented by response spectrum analysis.

2. Literature Review

The connecting girders play an important role in enhancing the seismic response of the double wall system, which can generate the power dissipation source in the structural model, and it can also be effective in resisting the failure due to the inherent

change in the stiffness. So the coupled shear wall system should have high rigidity, high strength, and high power dissipation to resist earthquake forces.

Many experiments have been conducted to get the best response for different patterns or alternative coupled beam models. A variety of numerical and experimental research has been conducted. The response of the steel coupling beam had been presented by [1] and [2], where they investigated the seismic behavior of steel hybrid coupled shear wall systems and suggested different provisions for design purposes. Several researchers have considered the evaluation of the load-displacement response of the coupling shear wall system [3-9]. In New Zeland, the different experimental for resistance the seismic demand had been executed by using the confined diagonal reinforcement [10], and all instruction and recommendation commitment in the ACI 318-08 Building and codes had been taken into consideration in the experiments [11] and [12] used the diagonal reinforcement for the short coupling beams.

ACI (American concrete institute) in 1999 proposed new representative modeling for the reinforcement layout, which comprises confined diagonal and transverse bars in the cross-section beam, the confinement by transverse reinforcement to prevent the buckling effect had been used. However, the difficulty in the construction short coupling beam with diagonal and transverse bars has been needed to solve (ACI 318-08). [13] suggested an alternative solution by avoiding the hoops and the diagonal reinforcement of the confining cross-section beam. In recent years, steel has been widely used in the composite section, so different researchers suggested the vital alternative for using the diagonal reinforcement by composite coupling beams. It can be sorted into two types, the encased steel plate and the concrete-filled steel plate. One of the biggest advantages of the steel coupling beam is the combined behavior of ductility, stiffness, and strength which can cause the best overall response in the structure system and improve the hysteretic behavior. The steel coupling beam can be used in the architecture restrictions affecting the height of the building, which requires the prevention of the deep beam. Moreover, the ductility behavior of the plastic hinges can be composed based on shear walls and at the ends of the coupled beam.

The interaction between the coupling beam and shear wall contributes to resisting seismic, and wind loads, so high shear resistance and dissipation energy have been

the requirements for successful interaction. The coupling beam can be divided into different patterns, where the conventional coupling beam contains the longitudinal and transverse bars for enhancing the seismic behavior, in which the moment resistance frames in almost building are accompanied with the coupling shear wall system, which is spread in the taller building [14]. On the whole, the resistance of lateral load can be generated by the shear wall system, but due to the architectural requirements, the openings for each floor level cause creating the coupling beams between isolated walls, and hence, the transferring of the vertical forces between shear walls can be achieved by the coupling beam, and also a portion of the overturning moment [15]. For this reason, the coupling beam can help reduce the overturning moment which happens in the individual shear wall and hence provides means for energy dissipation system in the resistance of seismic loads [16]. The behavior of the coupling beam should be in a flexible manner, yield before the shear wall, the over coupling behavior should be avoided in the design of the shear wall system, which causes the isolated wall behavior [17-23].

Many researchers declared different patterns for the coupling beam, which improved the response against the seismic load. Although the coupled beams in almost cases had been constructed widely as the conventional RC material, the other material had been used in the construction in recent years. Typical the evolution of coupling beams depends upon the strength, stiffness, the coupling beam insertion length [24], and the strength attribution of the slab in the composite steel coupling beam have been analyzed [25], the strength and ductility of the composite beam also have been studied. [26] investigated the behavior of the combination between the RC beam and the steel members.

The stability of hysteretic response in the reinforced coupling beams under seismic loading needs a high level of detail, including the confinement of beam concrete and adequate containment of the steel reinforcement in the coupled beam. This caused heavy reinforcement to execute different techniques instead of the convention coupling beam [27]. Several researchers investigated the alternative solution obtained using steel coupling beams with sufficient embedment length in the coupled shear walls [15].

The stiffness, strength, and ductility of the coupled beams can be affected by the response of the coupled shear walls, and the failure modes of the coupling beams with a small ratio (Length/Depth) has been demonstrated by [11, 12, 28, 4, 23], but the diagonal reinforcement in the coupled beam causes difficulty in execution and also increasing cost, this effect can return to congestion of the reinforcement bars which can consider as the milestone of the execution problem. For the structure analysis, The longitudinal reinforcement bars in the coupling beams should be

adequate to resist the flexural failure, and the shear force V_b can be calculated by Eq.(1)

$$V_b = \frac{2M_s}{L} \quad (1)$$

where M_s is the bending strength according to ACI318-05, and L is the length of the coupling beam.

ETABS is an engineering software tool that caters to multi-story building analysis and design where three-Dimensional model can be created [29]. Also, advanced and basic models under dynamic or static conditions may be evaluated, so it can be a useful tool to predict the behavior of the coupled wall system. Different methodologies for representing the models can generate to represent the modeling. [30] investigated the different types of models for composing the shear wall system, is divided into three elements such as shell – shell element, shell frame elements, and frame-frame elements, using two-dimensional shell frame model and an equivalent frame model are appropriate models for the analysis of the coupled shear wall models. However, all representative models had been created into two-dimensional only without considering the effects of the slab. Due to a lack of knowledge about its response, there are difficult to predict the response of slab on the coupling beam system under dynamic load, so the study seeks to develop the model representing the interaction between them.

In [31], the author chooses a new strategy for describing the diagonal reinforced coupling beam under cyclic loading, but the studying did not involve the effects of floor slabs on the behavior of the coupling system. Shim [32] studied the effects of thickness slab with two experimental cases with zero and 100 mm thick slab, which means little factors with limits conditions. So there is an urgent need to fully study the response of the combination between coupled beam system and the slab element to get full knowledge about the inherent change in the response due to these effects. Variety experimental research had been executed without consideration for the slab effects, from past research results, there are deduced for the longitudinal strain under the loading effect [33, 34]. However, there is a shortage in representing the slab constraints. [35] investigated the constraining effect of the slab diaphragm with high rigidity of the shear walls and represented the constraint in the experimental test by using the longitudinal bar in PVC pipes erected at the middle of specimens. [35] concluded that the longitudinal constraint has a significant effect on the strength of the conventional coupling beam but maybe a remarkable effect on the diagonal coupling beam. However, this study is insufficient to get the realistic response for the interaction between the shear wall coupling system and the slab element.

3. Methods

3.1. Modal Response Spectrum (RS) Method

In the past, it was difficult to calculate the basic mode superposition method, which is considered a linear elastic analysis, to get the complete response of the structure. This method has disadvantages due to the need to produce a large amount of information which requires computational effort to produce the complete time history response of joint displacement and forces. The response spectrum method can be used to solve this problem and expect the behavior of the structure under seismic loading, which depends upon the max values for each mode to get the behavior of the structure under earthquake load.

The study [36] had an effective role in spreading and accepting the concept of the earthquake response spectrum created by M.A Biot 1932 to expect the ground motion response and its effects on the structures.

In the last century, the response spectrum provides the conventional manners to get the peak response of all possible linear SDF systems, which consider the main concept in earthquake engineering. It presents a convenient means to summarize the peak response of all possible linear SDF systems, and it can help to provide the knowledge of structural dynamics for the design and add the concept of the response spectrum in the design codes.

For three-dimensional seismic motion, the seismic equation of motion can be calculated from Eq. (3).

$$\ddot{y}(t)_n + 2 \zeta_n w_n \dot{y}(t)_n + w_n^2 y(t)_n = p_{nx} \ddot{u}(t)_{gx} + p_{ny} \ddot{u}(t)_{gy} + p_{nz} \ddot{u}(t)_{gz} \quad (3)$$

where $p_{ni} = -\phi_n^T M_i$, the three Mode Participation Factors are defined by i as equal to x , y , or z .

To get the response of the building under earthquake, It can follow the steps, the first step: gets the maximum peak forces and displacement for each direction, the second step: obtain the response for three orthogonal directions, which is necessary to estimate the maximum response from the three components of earthquake motion acting at the same time.,

The peak response of the response spectrum equation can get from the following Eq. (4).

$$\begin{aligned} u_o(T_n, \zeta) &= \max_t |u(t, T_n, \zeta)| \\ \dot{u}(T_n, \zeta) &= \max_t |\dot{u}(t, T_n, \zeta)| \\ \ddot{u}(T_n, \zeta) &= \max_t |\ddot{u}(t, T_n, \zeta)| \end{aligned} \quad (4)$$

The deformation response spectrum is a plot of u_o against T_n for fixed ζ . A similar plot for \dot{u}_o is the relative velocity response spectrum, and \ddot{u}_o is the

acceleration response spectrum.

Response-spectrum analysis (RSA) is a linear-dynamic statistical analysis method that can be calculated the maximum seismic response for each natural mode. It can measure pseudo-spectral acceleration, velocity, or displacement as a function of the structural period for given time history and level of damping. Indeed, the concept of the response spectrum is applicable for all types of structures where the modal participation does not less than 90% to the structure's mass in each orthogonal direction. For the response spectrum method, Square Root of Sum of Squares (SSRS) is applied as a directional combination method and used the Complete Quadratic Combination (CQC) for the modal combination method. According to Finite element modeling, the number of vibration modes is defined to achieve more than 90% from mass participation as a response spectra condition.

The seismic zone considered in this study is zone 5B, and the shape of the spectrum is type 2 as per the Egyptian zoning system with Seismic zone factor = 0.3 g, the important factor $\gamma = 1$, soil class 'C' as per referring to dense and stiff soil and a soil factor. R is taken considering the vertical loads, and the total base shear is resisted by the shear wall structure ($R = 5$), $T_b = 0.1$ sec, $T_c = 0.25$ sec, and $T_d = 1.2$ sec. The response spectrum curve can be shown in Fig. 1.

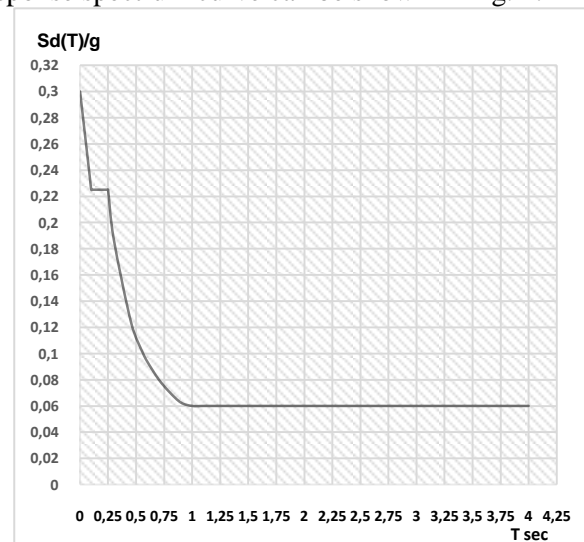


Fig. 1 Response spectrum curve

Fig. 1 demonstrates the response spectrum curve, which is used to represent the seismic analysis effecting on moment resistance frame; for nonlinear seismic analyses, a total seismic mass, including self-weight Dead Load (DL) + 0.25 LL + FL (flooring load), is involved according to [37].

3.2. Diaphragm Modeling

Lateral and gravity loads can be supported by a three-dimensional framework of structural elements of construction building, although the integral acting for building structure between all components had happened. There is a need to separate the effects of

elements to study the effects of seismic forcing systems according to Building Code Requirements for Structural Concrete (ACI 318-14) [10]. On the other side, the continuous load path contains vertical and horizontal elements to transmit gravity, wind, and seismic loads. The horizontal elements typically consist of diaphragms that transmit seismic loads from the flooring system to the vertical elements. The slab system's diaphragm is connected not only to the vertical elements but also to the coupling beam system. On the whole, the floor diaphragm means the interaction of the lateral load with lateral load resisting vertical elements is achieved by using the floor system. So, the interaction between the diaphragm and the coupling beams system has been represented to transmit the seismic load effectively.

3.3. Rigid Link Modelling

The rigid links consider as a representative model referring to the kinematic relationship between the selected nodes in the finite element model so that it can be used widely in structural modeling. Fig. 2 shows the rigid link connection between several nodes S1, S2 with a node M; node M is the master node, and other nodes S1, S2 ..., Si are the slave nodes [38].

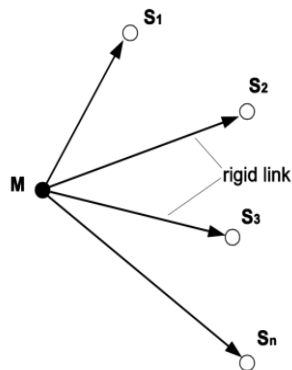


Fig. 2 Model of the rigid link

Based on the theorem of rigid body kinematics, Eq.(5) represents the rigid link modeling between master and slave nodes

$$\begin{pmatrix} U_{Si} \\ \theta_{Si} \end{pmatrix} = \begin{pmatrix} U_M + \theta_M \times \rho_{M-Si} \\ \theta_M \end{pmatrix} \quad (5)$$

$i \in [in]$

where U_M , U_{Si} are vectors of translational displacements of the nodes M, Si respectively, θ_M , θ_{Si} are vectors of rotation angles, ρ_{M-Si} is a radius-vector connecting the node M with a node Si.

3.4. Rigid Link between Coupled Beam and the Slab Diaphragm

The coupling beam for shear walls can be modeled by using the wall elements, which can be helpful to create the connection between the slab elements and the coupled beam. The rigid link can be useful to create correcting modeling for rigidity connection between them. In most cases, the beam can represent just be

attached to the node at the slab element, which is not correct and leads to not modeling in-plane rotational stiffness. So, the rigid link is a solution to create the correcting model, which transfers the bending moment from the node shell element to others and a shear force, as shown in Fig. 3.

The transferring shear forces from the shell node to the interior nodes without the rigid links can affect the stiffness of the shell elements, the node I for all links is the node connected to the node of the coupled beam. In contrast, node J is the end that extends into the nodes of slab elements; the J ends of all the rigid links should have their x, M_x , M_y , and M_z degree of freedom released. Only Y and Z degrees of freedom should connect from the J end to the interior shell elements node. This release configuration allows the shear forces to be transferred from slab elements into a coupled beam, and also, the shell element stiffness will not be adversely affected by the presence of the rigid link. Fig. 3 shows the rigid link in the structural modeling.

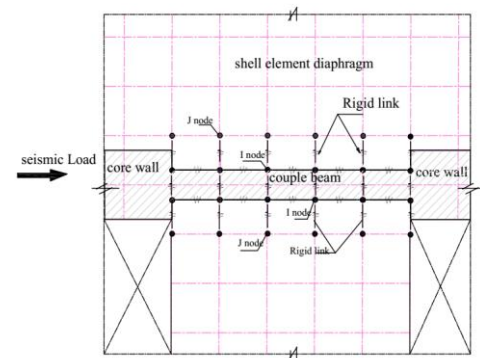
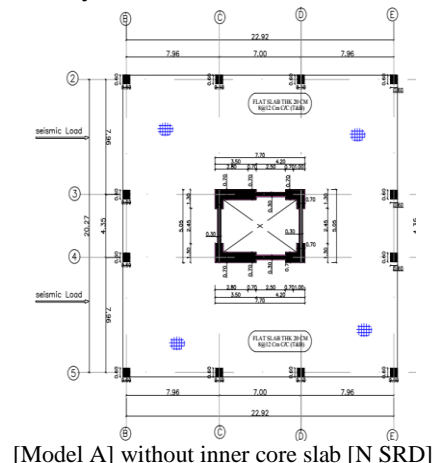
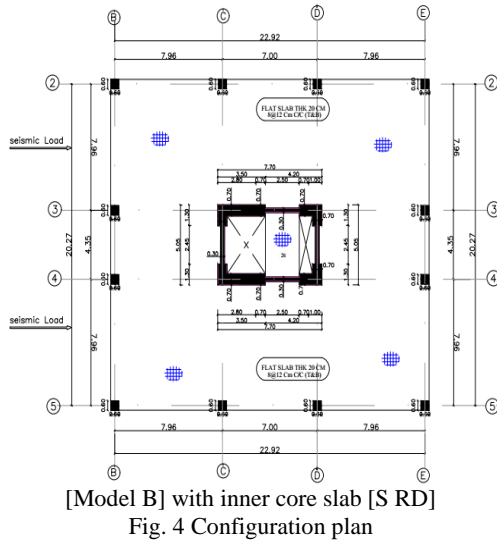


Fig. 3 Rigid link between the coupled beam and the slab elements

3.5. Study Cases

The study focuses on the effectiveness of the rigidity connection between the slab and coupled beam elements in the response of the structure building under seismic load. Accordingly, the results show the difference between their behaviors in case of existence slab or not as shown in Fig. 4, where model A and model B express the structure without slab and with slab, respectively.





[Model B] with inner core slab [S RD]
Fig. 4 Configuration plan

3.6. Mathematical Modeling

In order to execute the necessary analysis and hence get the results and recommendations, three structural models had been investigated (4-story, 8-story, and 12-story). The structural elements' dimensions have been determined using a preliminary design process. The dead loads comprise the self-weight and the flooring loading. The flooring load (FL) is equal to 1.5 kN/m², live load (LL) is taken by 2.5 kN/m² for each floor.

Fig. 5 illustrates the structural modeling for the coupling beam along with the stories with height 3.6 m, the dimension of the cross-section of the columns had been used as a preliminary design process is 60 X 60 cm, the slab thickness in the different modeling is 20 cm, all elements have been designed according to ACI 318 (10) and ECP 2008 code [37] to be safe. Consequently, the details of the cross-section of the coupled beam can be illustrated as shown in Fig. 6.

The concrete compressive strength C45 is chosen equal to 45 MPa, and the yield strength of steel type ST40/60 was assumed 400 MPa, Poisson ratio $\mu = 0.3$, Design base shears were determined for a Peak Ground Acceleration (PGA) of 0.3 g.

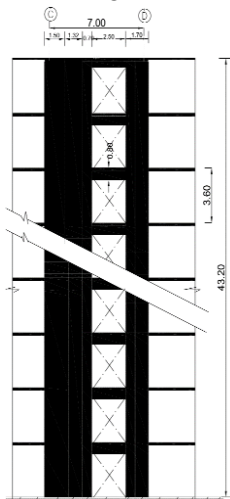
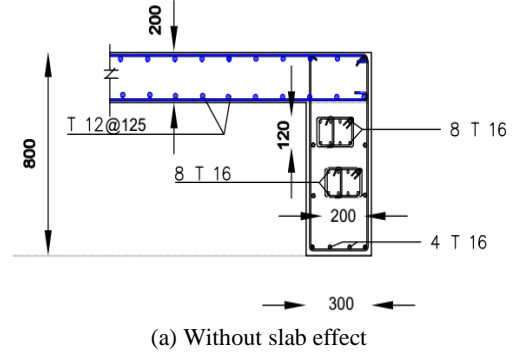
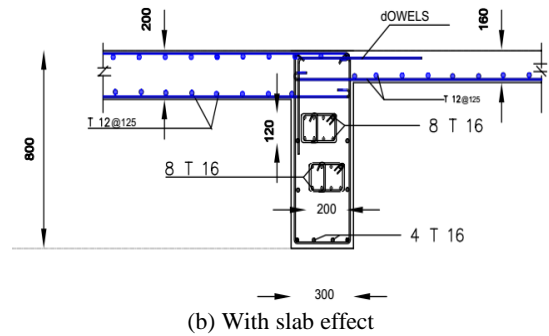


Fig. 5 The structural modeling for the coupling beam along the stories



(a) Without slab effect



(b) With slab effect

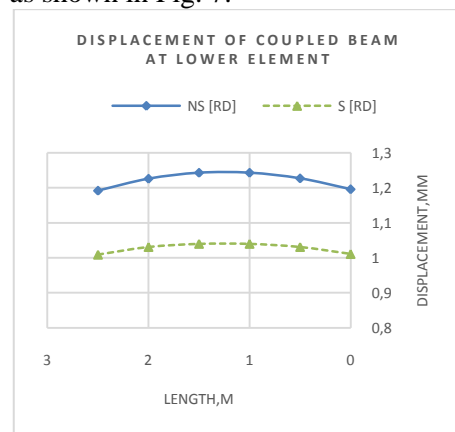
Fig. 6 The details of the cross-section of the coupled beam

4. Numerical Results and Discussion

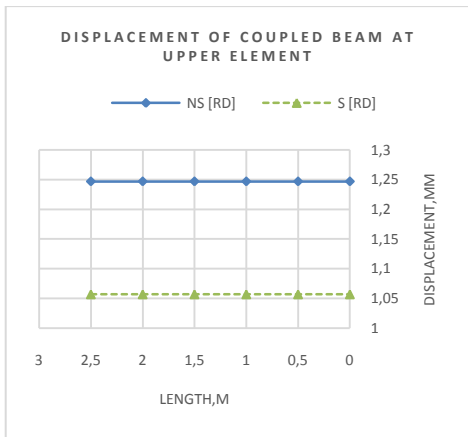
4.1. In Case of the Number of Stories Equal to Four Stories (Response Spectrum in X Direction)

4.1.1 Lateral Displacement U_x

The Rigidity connection between the coupled beam and slab elements has an important effect on the response of the coupled beam under the seismic loading. Fig. 3 shows the effects of rigidity connection between CB (Coupled beam) and SE (Slab Element) represented by using the rigid link between wall elements of the coupled beam and slab. Fig. 4 indicates the difference between two cases: No slab – [NS [RD], [Model A] and Slab [S [RD], [Model B], where the results show that the percentage of decreasing for lower wall elements of the coupled beam for [S [RD] compared to [NS [RD] is 16.33%, and also for the upper wall elements the decreasing can be reached to 15.24% as shown in Fig. 7.



(a) Displacement of coupled beam at lower element

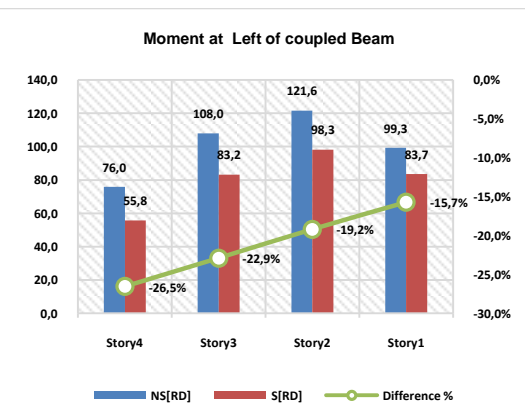
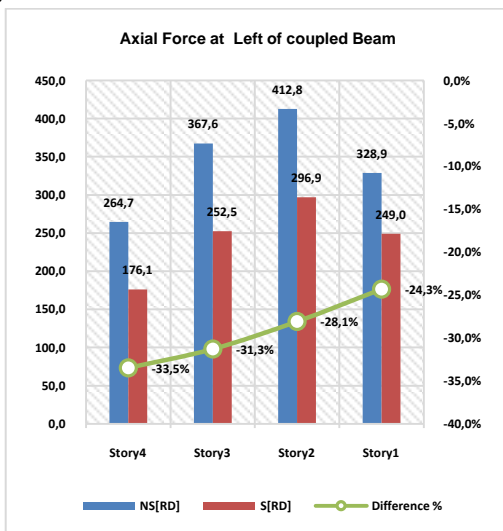
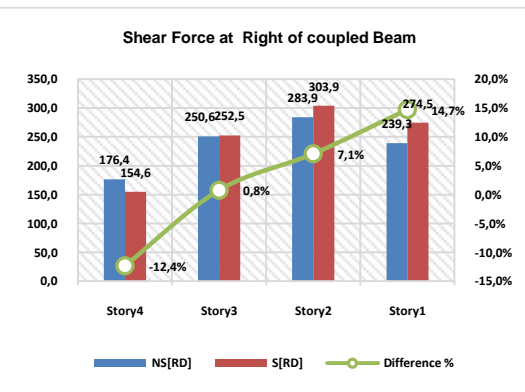
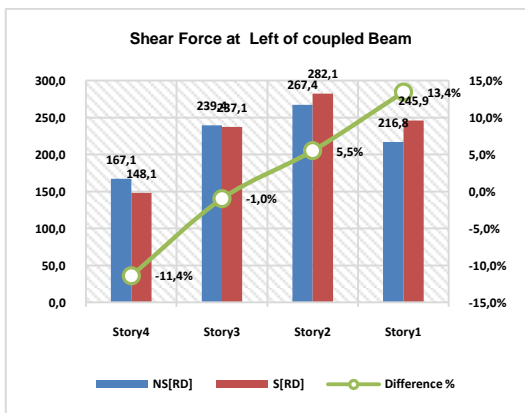
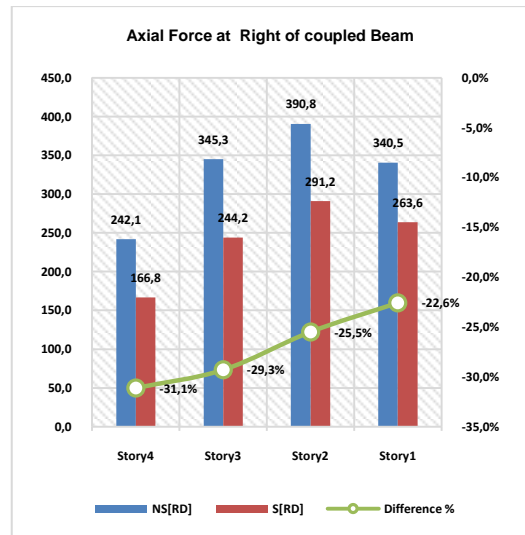


(b) Displacement of coupled beam at upper element
Fig. 7 Displacement of coupled beam

4.1.2. Straining Action of Coupled Beam

From analysis, it shows that there is variation between values of straining actions on the coupled beam along the height of the building for the cases studied [NS [RD] & [S [RD]]. Fig. 8 shows the path of deviation between values which indicate the reducing the values of straining action [Axial force, Shear, Moment], these are returned to the effects of rigidity connection between the coupled beam and slab, on another side, in case of shear force the reducing values appear only in the high level. Otherwise, the other forces [moment, axial force] the reducing appears along the height of the building, the percentages of reducing in values for the straining action can be as shown in Fig. 8:

- Axial force: the range of decreasing between -33.5% and -22.6%
- Shear forces: the range can be between -12.4% and 14.7%
- Moment: the range is between -26.5% and -11.1%



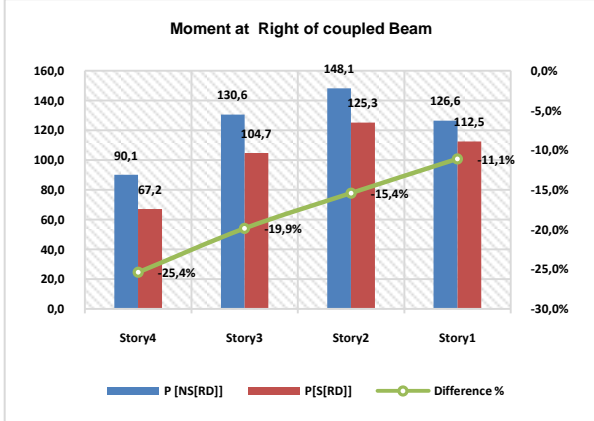
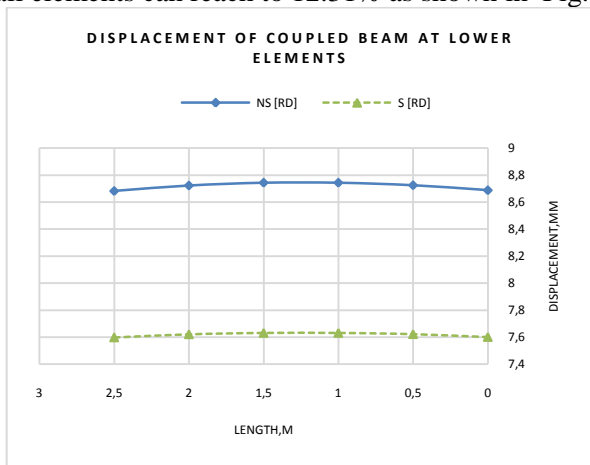


Fig. 8 Straining action of the coupled beam

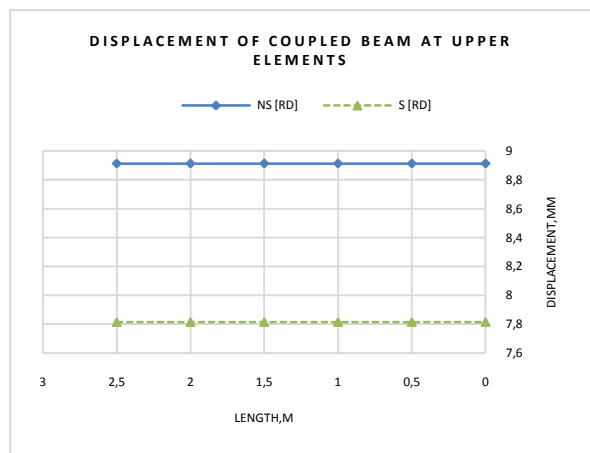
4.2. In Case of Number of Stories Equal to Eight Stories (Response Spectrum in X Direction)

4.2.1. Lateral Displacement U_x

Fig. 9 shows the effects of rigidity connection between CB (coupled beam) and SD (slab elements) in the case of [S (RD)] and [NS (RD)] at the upper level of stories. It can show the reduced value of the lateral displacement response, the percentage of decreasing for lower wall elements of coupled beam [S (RD)] for [NS (RD)] can be reached 12.73%, and also for the upper wall elements can reach to 12.31% as shown in Fig. 9.



(a) Displacement of coupled beam at lower element



(b) Displacement of coupled beam at upper element

4.2.2. Straining Action of Coupled Beam

Fig. 10 shows the path of deviation between values for eight stories, indicating the reducing values of straining action [Axial force, Shear, Moment]. So, the rigidity between the slab and the coupled beam is more effective in reducing the straining action [moment, axial force, shear force], and the percentages of reducing in values for the straining action can be as shown in Fig. 10:

- Axial force: the range of decreasing between -9.5% and -25.5%
- Shear forces: the range can be between -20.5% and 9.8%
- Moment: the range is between -33.1% and -14.5%

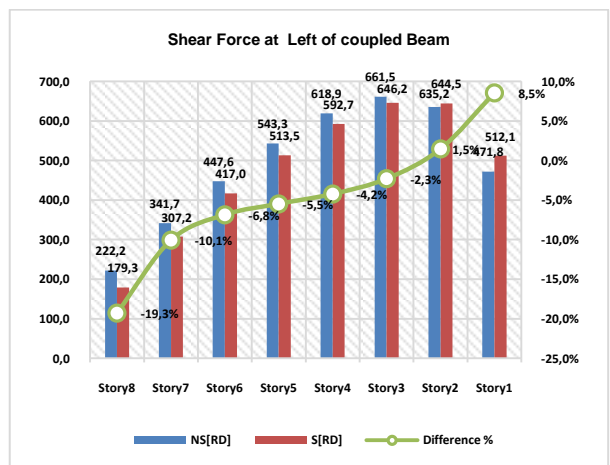
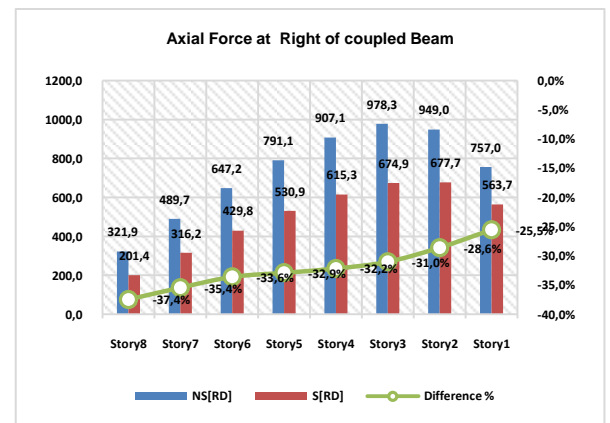
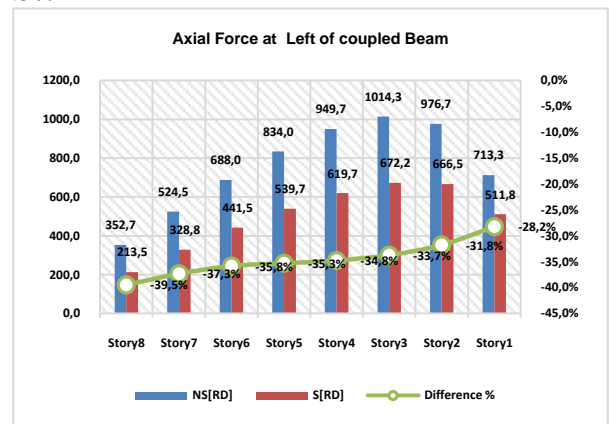
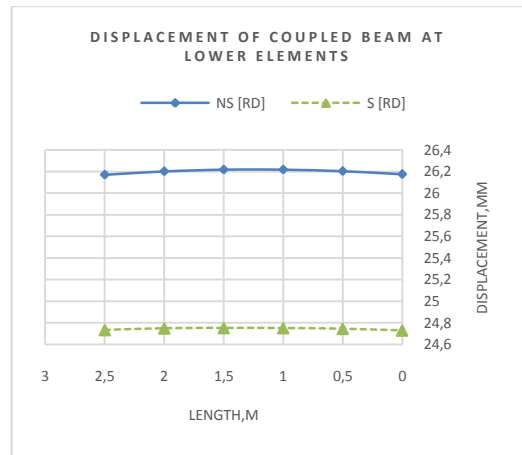
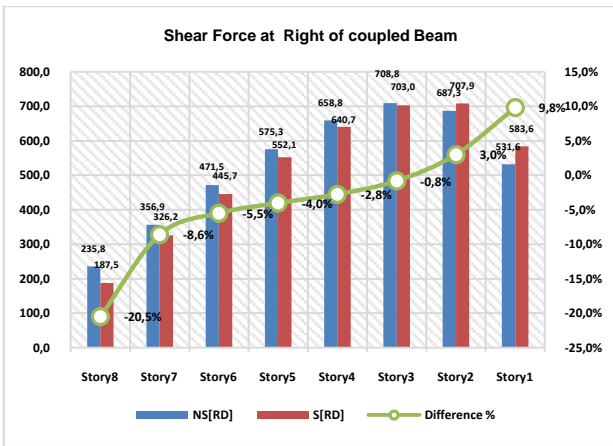
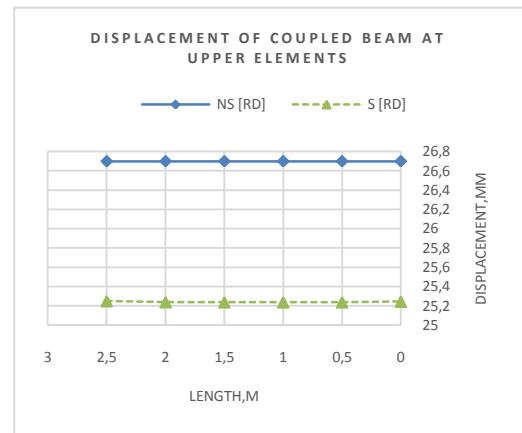
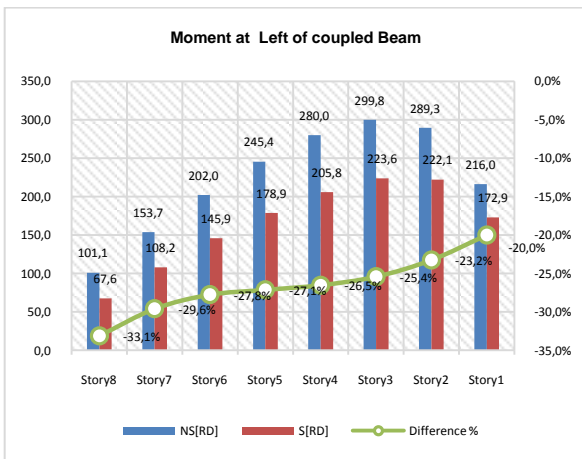


Fig. 9 Displacement of coupled beam



(a) Displacement of the coupled beam at lower element



(b) Displacement of the coupled beam at upper element

Fig. 11 Displacement of coupled beam

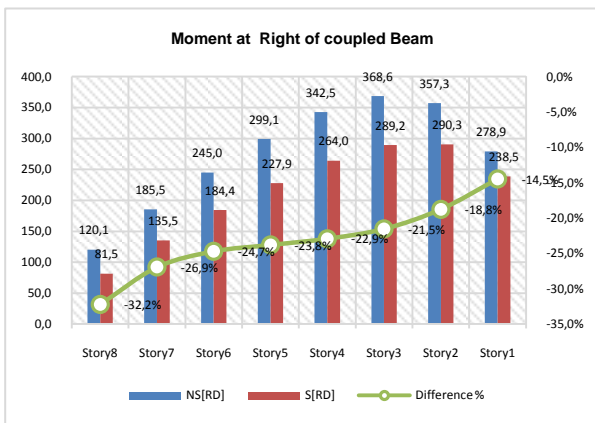


Fig. 10 Straining action of the coupled beam

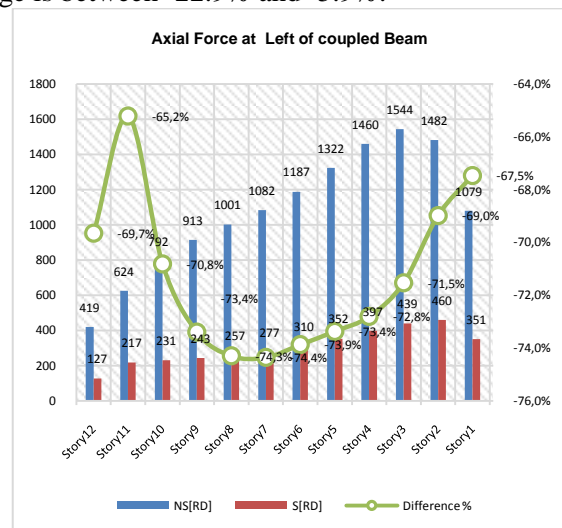
4.3. In Case of the Number of Stories Equal to Twelve Stories (Response Spectrum in X Direction)

4.3.1. Lateral Displacement U_x

Fig. 11 shows the comparison between two cases of study. It can be obvious the little reducing value of the lateral displacement response for [S [RD]] compared to [NS [RD]], the percentage of decreasing for lower wall elements of the coupled beam can be reached 5.59%, and also for the upper wall elements the decreasing can be reached to 5.48% as shown in Fig. 11.

4.3.2. Straining Action of Coupled Beam

Fig. 12 shows the path of deviation between values for twelve stories, which can reduce the values of straining action [Axial force, Shear, Moment]. Accordingly, the rigidity between the slab and the coupled beam is also more effective in reducing the straining action [moment, axial force, and shear force], the percentages of reducing in values for the straining action as shown in Fig. 12: Axial force: the range of decreasing between -75% and -65.4%; Shear forces: the range can be between -25% and 2.4%; Moment: the range is between -22.9% and -5.9%.



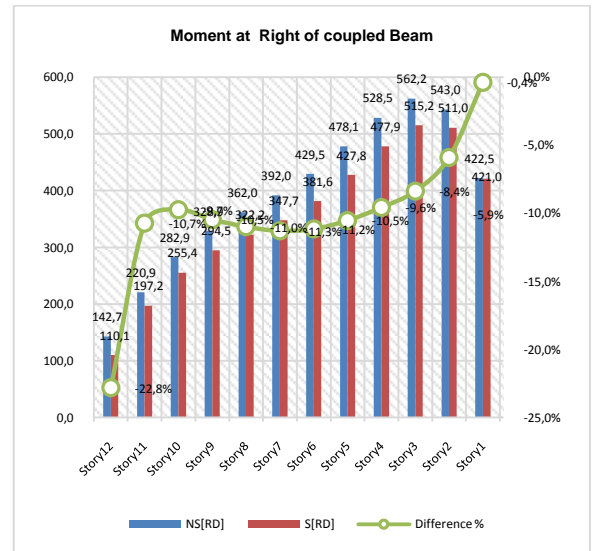
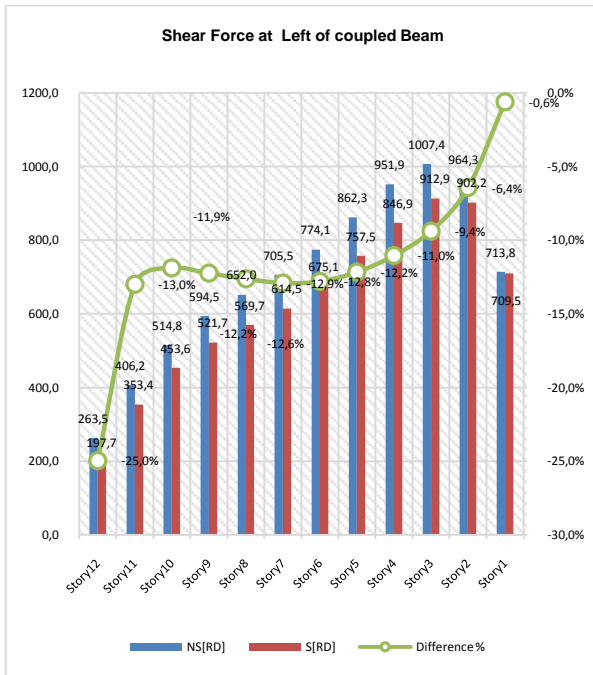
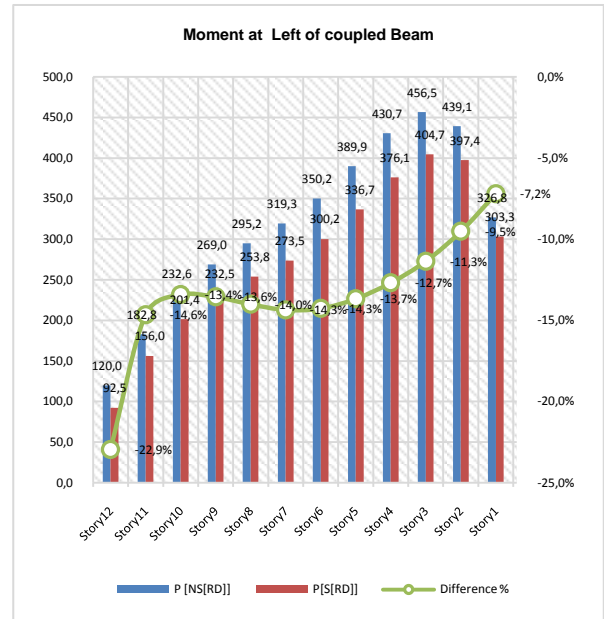
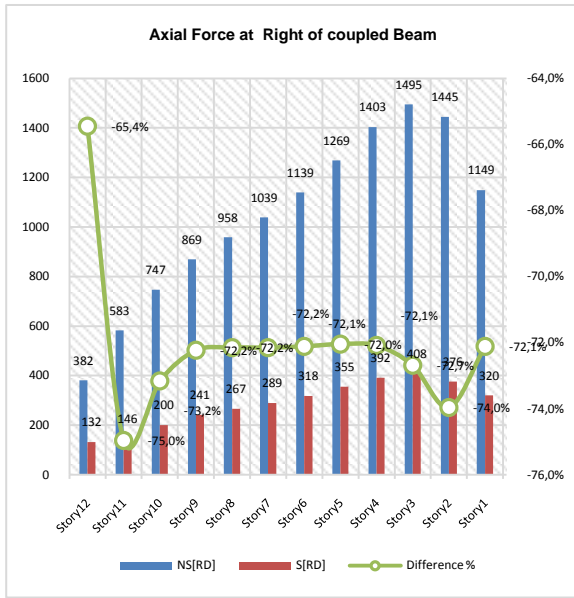
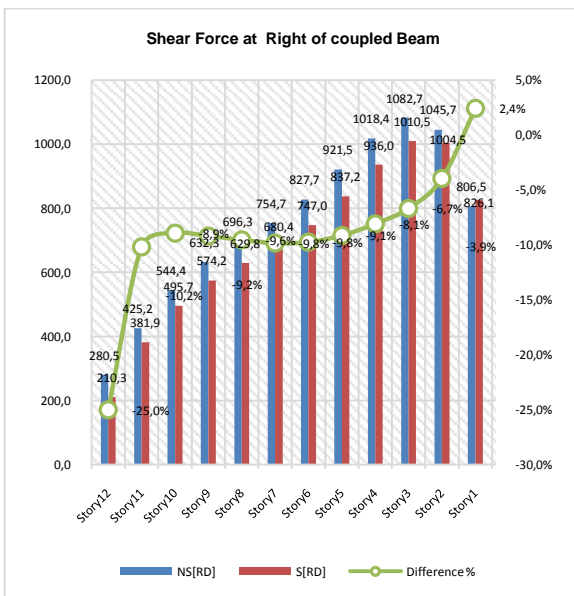


Fig. 12 Straining action of the coupled beam

4.4. The Overall Response of the Construction Building

4.4.1. The Story Displacement Response

The study also focuses on examining the lateral displacement response of the selected structural modeling for different cases, which may be helpful to understand the behavior of the structure building under the seismic loading. Fig. 13-15 show the effects of rigidity between slab elements and the coupling beam on the story displacement demand and compare the results between [NS [RD] and [S [RD], for discussion the cases can be divided into *first (the flour story building)*. Fig. 13 shows the decreasing of lateral displacement in the case of [S [RD] compared to [NS [RD] along with the height of the building, which can be reached to 15.21% at the top of the story building so that the rigidity connection can mitigate the response and improve the lateral stability.



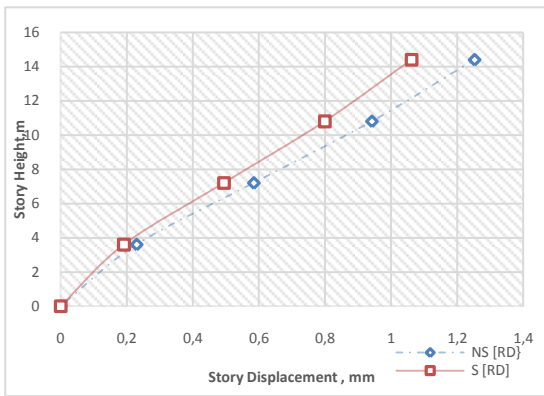


Fig. 13 Lateral displacement (four stories)

Second (the eight stories building): in the case of eight stories, there is reducing of the effects of rigidity on the mitigation of lateral displacement. Fig. 14 shows the decreasing of lateral displacement for [S [RD]] compared to [NS [RD]] along with the height of the building, which can be reached to 12.36% at the top of the building.

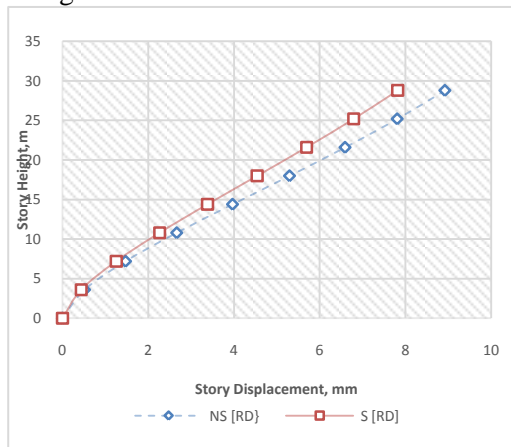


Fig. 14 Lateral displacement (eight stories)

Third (the twelve-stories building): Fig. 15 shows the effect of rigidity of the connection between the coupled beam and slab [S [RD]] compared to [NS [RD]] on the lateral response with increasing the height of the building, the decreasing of lateral displacement can reach 5.36% at the top of the building.

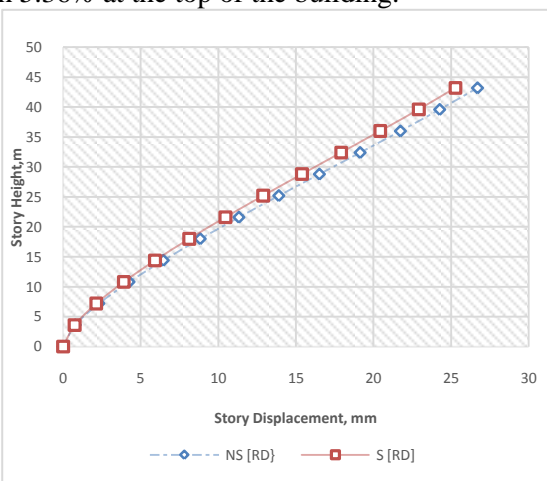


Fig. 15 Lateral displacement (twelve stories)

4.4.2. The Story Drift Response

Due to the importance of the drift effect, the study demonstrates the story drift for the studied cases to stand up the rigidity connection effect on the story drift response.

First (the four stories building): Fig. 16 shows that the decreasing of the max story drift occurs due to the rigidity connection between the coupled beam and shell element of the slab along with the height of the building [S [RD]]. It can reach 16.43%, so the rigidity system between CB and SES can mitigate the response and improve the lateral stability.

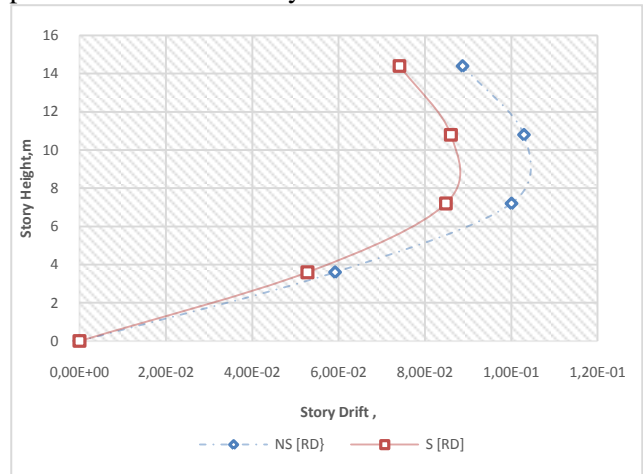


Fig. 16 Story drift (four stories)

Second (the eight Stories building): in the case of increasing height of building until 28.28 m, the decreasing of the max story drift occurs for [S [RD]] compared to [NS [RD]] can reach 12.92%, as shown in Fig. 17, so the effects of rigidity still continuity with increasing height of the structural building.

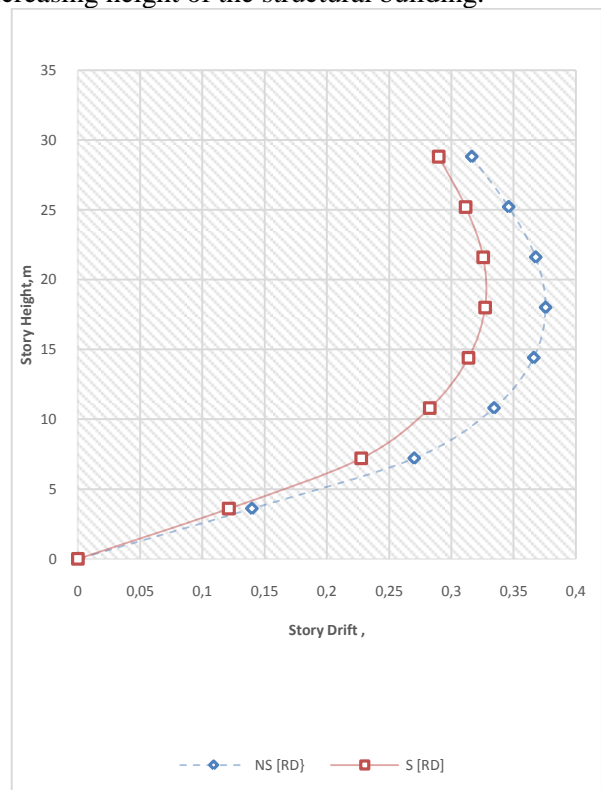


Fig. 17 Story drift (eight stories)

Third (the twelve Stories building): Increasing the height until 43.2 m can lead to weak effects of rigidity connection. Fig. 18 shows the little effect of rigidity of connection on the story drift response with increasing the height of the building; the decreasing of max story drift can reach 6.41%.

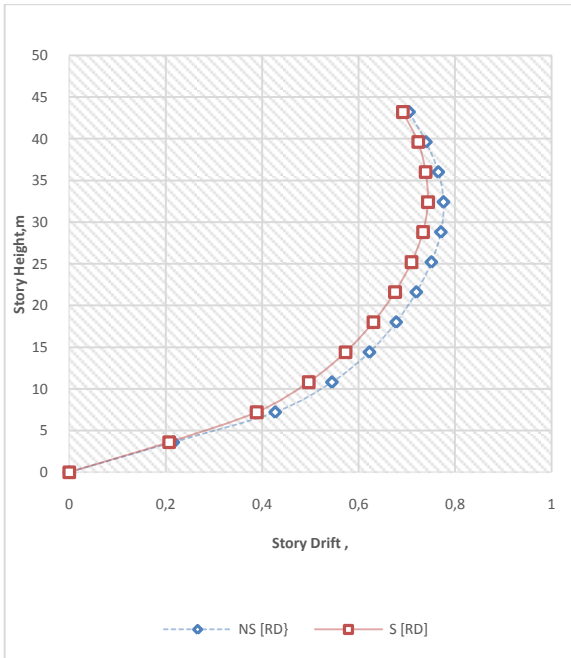


Fig. 18 Story drift (twelve stories)

4.4.3. The Story Moment Response

All models of stories [4 & 8 & 12 stories]: the existence or absence of the slab between coupled beam as shown previous Fig. 4 nearly has not to affect on the moment response which means the connection rigidity between CB and SB has not biggest effect on values along with the height of the building. Fig. 19 illustrates the variations of response for all study cases.

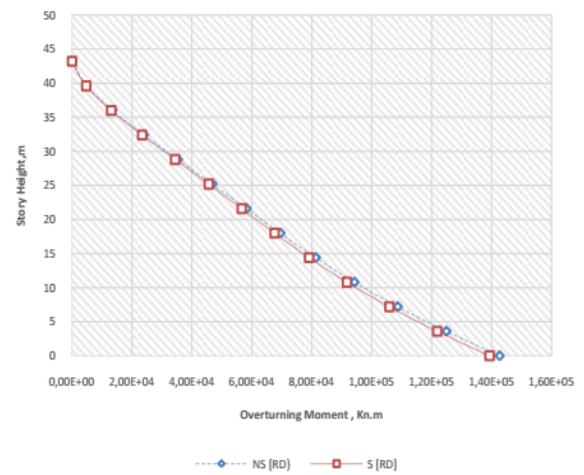
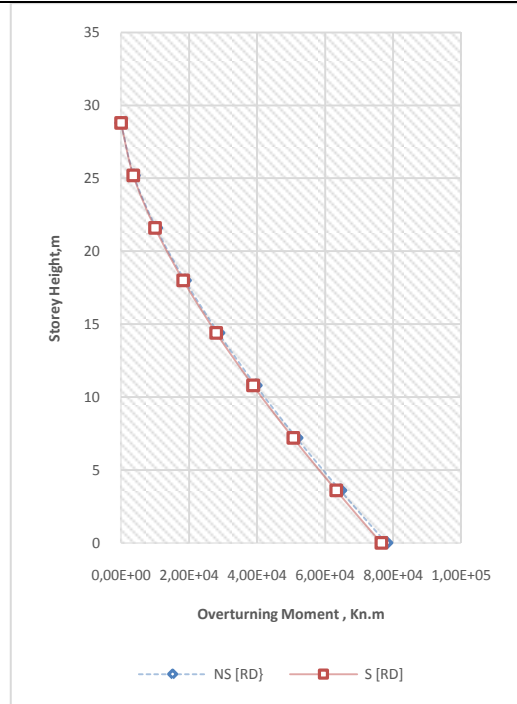
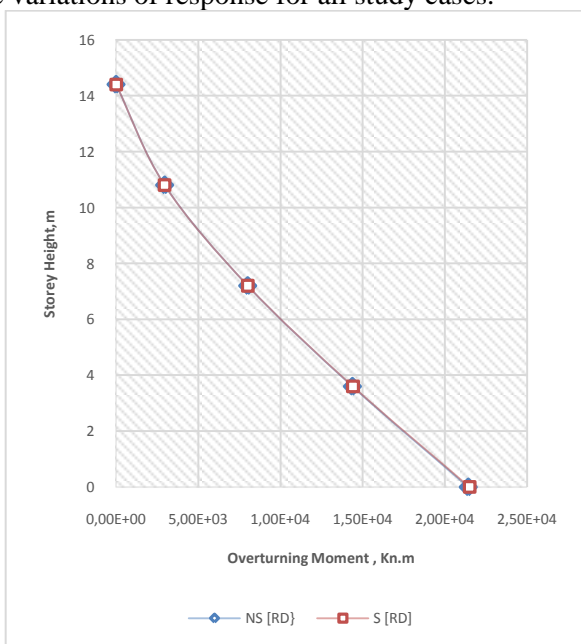
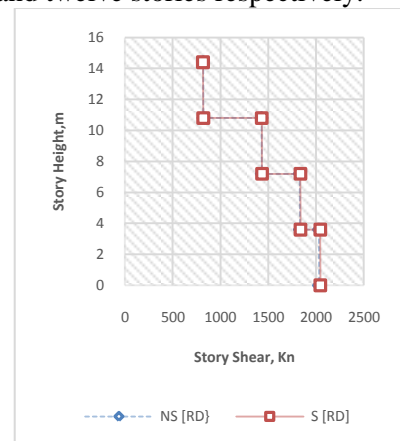


Fig. 19 Story moment (4, 8, 12 stories)



4.4.4. The Story Shear Response (RESX)

All modeling of stories [4 & 8 & 12 stories]: Fig. 20 shows nearly no deviation between the shear stories for two cases of modeling [S [RD] & [NS [RD]], the percentage of increase in the shear force at the basement can be reached to 0.64%, 2.64%, 1.67% for four, eight and twelve stories respectively.



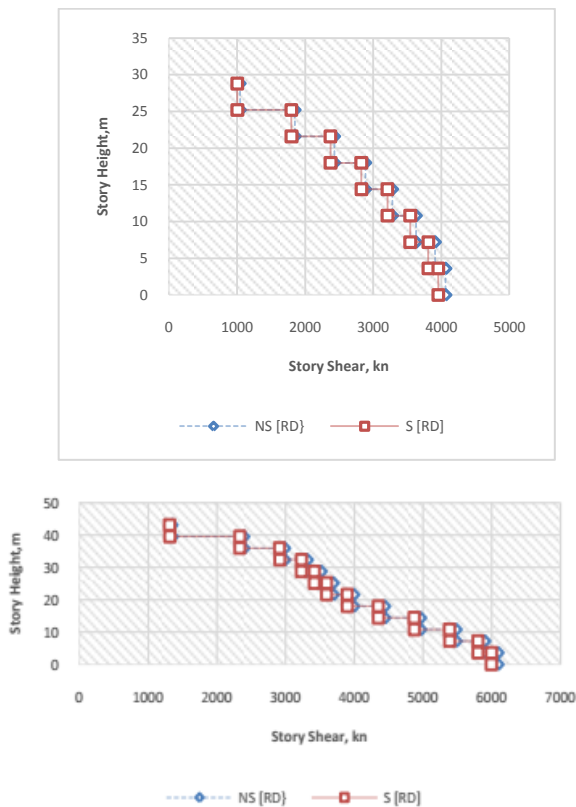


Fig. 20 Story shear (4, 8, 12 stories)

5. Conclusion

The rapid urbanization process has increased the number of tall structures being built. Due to reinforced concrete walls being traditionally favored to resist seismic demands, they are commonly used as lateral load resisting features in multi-story buildings. A coupled shear wall comprises coupling beams and wall piers and is part of a shear wall system. It adds more apertures to the architecture, increasing the functional flexibility. Furthermore, coupled shear walls, which connect separate walls by coupling beams, have been utilized to effectively withstand a major percentage of the overturning moment caused by lateral loading, including wind or seismic loading via the coupling effect's frame action. In recent years, Flat plate slab thickness has increased dramatically, with the slab stiffness effect of coupling beams.

Moreover, due to its unproven effectiveness, the effect of slab stiffness has not been investigated in the structural design of coupling beams. In addition, there are a few pieces of research for studying the slab effect on the coupled beam, and also, in almost studies, the results had been concluded from experiments, in other words, there as far as we know, no previous research has represented the model for the connection between the slab and coupled beam. Therefore, the study cases have investigated the rigidity connection effectiveness between the slab and coupled beams in reducing the structure response for the seismic loading [with and without slab]. Although this effect does not consider the design provisions, it has a significant effect on the

seismic response. On the whole, it can reduce lateral deformation and its straining actions. On another side, the mathematical models are developed using ETABS software to determine the seismic response demands. The measured responses include the coupled beam's lateral deformation and straining actions, lateral displacement, story drift, story shear force, and overturning moment. For all models, the variation of responses for study cases is being investigated, and the results are compared with that of the reference model of no existence slab between coupled beams [NS [RD]]. Two cases of studies [with and without slab] for the input response spectrum are investigated and compared; the response spectrum is applied along X-direction. The results can summarize as follows:

- Lateral deformation: The rigidity connection between the slab and coupled beams can reduce the lateral deformation of the coupled beams, which can reach 16.33%, 12.75%, 5.59% compared to [NS [RD]] for 4, 8, 12 stories, respectively.

- Straining actions of the coupled beams: the variation between values of straining actions on the coupled beam along the height of the building for the cases studied [NS [RD]] & [S [RD]] has been demonstrated. Fig. 8, 10, 12 show the path of deviation between values along with the height of the building in 4, 8, 12 stories which indicate the reducing values of straining action [Axial force, Shear, Moment] returned to the effects of rigidity connection between the coupled beam and slab.

- The story lateral displacement and story drift demands of [S [RD]] models are smaller than those of the reference model [NS [RD]]. The response reduces due to the rigidity between the slab and coupling beams, which is useful for structural modeling. It can take into consideration in the design conditions, the decreasing of lateral displacement for [S [RD]] compared to [NS [RD]] along with the height of the building in case of four, eight, twelve stories can reach 15.21%, 12.36%, 5.36% respectively, and the decreasing of the max story drift can reach to 16.43% 12.92%, 6.41%.

- The absence or existence of the slab between coupled beams nearly has not affected the moment and shear story response, which means the connection rigidity between CB and SB has not significantly affected the change in values and the height of the building.

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